GUIDELINE A-5

Atmospheric Emissions from Stationary Combustion Turbines

Legislative Authority:

Environmental Protection Act, Sections 6, 9, and 14
Ontario Regulation 346

Responsible Director:

Director, Program Development Branch

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SYNOPSIS

The primary purpose of this policy is to control emissions of NO_x, a key ground level ozone precursor, from new and modified stationary combustion turbines, by specifying atmospheric emission limits for nitrogen oxides, sulphur dioxide, and carbon monoxide. The emission limits for nitrogen oxides and sulphur dioxide are expressed as emissions by weight per unit of net useful energy output (grams per gigaJoule) and are intended to promote energy efficiency and pollution prevention.

This policy applies to all new and modified stationary combustion turbines using gaseous, liquid or solid-derived fuels. The elements of the policy are described in MOEE Guideline "Emission Limits for Stationary Combustion Turbines".

The policy will be enforced by imposing conditions in Certificates of Approval. Monitoring and recording activities will be required to demonstrate compliance with this policy and the associated guideline.

1.0 INTRODUCTION

Ground-level ozone is caused by the atmospheric reaction of two precursor pollutants, nitrogen oxides (NO_x) and volatile organic compounds (VOCs). In November, 1990, the Canadian Council of Ministers of the Environment (CCME) endorsed the "*Management Plan for Oxides of Nitrogen (NO_x) and Volatile Organic Compounds (VOCs), Phase I"*. The Plan was developed to suggest ways to reduce emissions of the two precursors of ground-level ozone, in three ozone problem areas in Canada, the Windsor-Quebec Corridor, the Lower Fraser Valley area of British Columbia and the Saint John Area of New Brunswick. Twenty-five percent reductions in emissions of both NO_x and VOCs were recommended in the Ontario portion of the Windsor-Quebec Corridor (based on 1985 levels), as significant first steps towards reducing harmful levels of ground-level ozone. The Plan also outlined various initiatives which could be adopted, either nationally or locally, to reduce NO_x or VOCs emissions. Emission limits for new stationary combustion turbines was one of the initiatives proposed. To facilitate development of provincial implementation regulations or policies, a nationally represented multi-stakeholder task force was organized by Environment Canada. The document *"National Emission Guidelines for Stationary Combustion Turbines"* was published in December, 1992.

The Ontario Ministry of Environment and Energy has adopted these national guidelines as the basis for MOEE Policy **A-5**. The implementation of this policy is defined in this Guideline.

Through adherence to this guideline the policy will limit contaminant emissions from new and modified stationary combustion turbines using gaseous, liquid or solid-derived fuels by specifying emission limits. The emission limits for nitrogen oxides and sulphur dioxide are expressed as emissions by weight per unit of net useful energy output (grams per gigaJoule) and are intended to promote energy efficiency and pollution prevention through reduced fuel usage and the promotion of new control technologies, such as low NO_x combustors. An emission concentration limit for carbon monoxide emissions is also stipulated to prevent carbon monoxide emissions from significantly increasing as a result of efforts to comply with the nitrogen oxide emission limit. Monitoring and reporting requirements to demonstrate implementation and compliance with the emission limits are also included in the guideline.

Combustion turbines that comply with the requirements of this policy are expected to demonstrably reduce emissions of contaminants and assist in achieving the objective of the CCME Management Plan. The stationary combustion policy and guideline will be implemented by imposing conditions in Certificates of Approval. Once the proponent has established the energy efficiency of the process emissions limits in parts per million by volume (ppmv) will be determined in accordance with the guideline.

2.0 DEFINITIONS

Auxiliary Burners: this refers to the use of equipment to burn various types of fuel to reheat the combustion turbine exhaust gases.

Combustion Turbine: A combustion turbine is an engine which operates according to the Brayton thermodynamic cycle, in which fuel is burned and the products of combustion at a high temperature are allowed to expand through a rotating power turbine thus producing a net amount of motive power.

Combustion Turbine Facility: A combustion turbine facility includes the combustion turbine, the steam turbine (if applicable), the fuel handling equipment, related pollution control and flue gas handling equipment, and equipment required to directly recover energy from the exhaust gases. For simplification of thermal energy measurement, it excludes the downstream heating, cooling and industrial processes which utilize thermal energy recovered from the facility.

Contaminant: Means, for the purposes of this guideline, oxides of nitrogen of the form NO_x (NO and NO_2), oxides of sulphur of the form SO_x and measured as sulphur dioxide and the compound carbon monoxide.

Gaseous Fuel: A fuel which, as received, at atmospheric conditions is a gas.

Liquid Fuel: A fuel which, as received, at atmospheric conditions is a liquid.

Lower Heating Value: Lower Heating Value (LHV) of the fuel is the energy released during combustion of the fuel, excluding the latent heat content of the water vapour component of the products of combustion.

Modified Combustion Turbine: For the purposes of this Guideline a modified combustion turbine is defined as any combustion turbine facility which has been subjected to physical change or change in method of operation which results or may result in:

(a) an increase in emissions (in grams per second at maximum capacity) of any contaminant; or,
(b) the emission of a contaminant which was not previously emitted.

New Combustion Turbine: For the purposes of this Guideline, a new combustion turbine is defined as a combustion turbine which the Ministry receives an application for Certificate of Approval on or after June 1, 1994 for combustion turbines with maximum ratings of over 20 MW; and November 30, 1994 for combustion turbines with maximum ratings of 20 MW or less.

Oxides of Nitrogen (NO_x): NO_x refers collectively to nitric oxide (NO) and nitrogen dioxide (NO_2) expressed as a nitrogen dioxide equivalent.

Peaking Combustion Turbine: A peaking combustion turbine is a combustion turbine which is ordinarily used to supply electric or motive power at periods of high demand or during unforseen outages. Such a unit will not usually operate more than 7500 hours in any 5 year period and, in those years, a total of no more than 3000 hours during the months of May, June, July, August and September.

Pre-Test Plan: A summary of the sampling protocols and testing to be employed by the proponent during emission source testing of the Combustion Turbine.

Reference Conditions: refers to a reference state of 15 degrees Celsius ambient temperature, 60 percent relative humidity and 101.3 kiloPascals barometric pressure.

Solid-Derived Fuel: A fuel which, as burned, is derived from biomass or by some process such as gasification or liquefaction of coal.

Stand-By Combustion Turbine: A stand-by combustion turbine refers to a combustion turbine which operates less than 100 hours per year and is not required for the supply of energy or motive power to meet normal system operational requirements.

Thermal Efficiency: thermal efficiency is the fraction of the total energy input which is transformed into net useful energy output, usually expressed as a percentage on a lower heating value basis.

3.0 ABBREVIATIONS

CCME	Canadian Council of Ministers of the Environment.
MW	Megawatt of power.
g	Gram.
GJ	gigaJoule, (10^9) Joules of Energy.
ppmv @ 15% O_2	Parts per million, on a volume basis, at 15 percent oxygen content in the exhaust gases.
NO_x	Oxides of nitrogen.
CO	Carbon monoxide.
SO_2	Sulphur dioxide.

4.0 APPLICABILITY OF THE GUIDELINE

This guideline applies to all new and modified combustion turbines as defined in the Definitions, Section 2.0. The following are exempt from this guideline:

- stand-by combustion turbines;
- combustion turbines used for emergency duty;

- combustion turbines used in research, development, and field demonstrations;

- combustion turbines under repair (including temporary replacement units being used while the original unit is under repair) or being tested;

- peaking combustion turbines smaller than 3 MW.

General Notes

i) In the case where multiple new small combustion turbines are installed instead of a single large unit, the applicable unit size for the purposes of this Guideline will be the sum of the individual unit power ratings (for all New Combustion Turbines). While it is recognized that operational requirements may dictate the use of several units, multiple small units shall not be used to evade the more stringent limits applicable to larger units.

ii) In the case where a combustion turbine facility uses auxiliary burners, the Guideline limits apply to all fuel consumed by the combustion turbine facility. The fuel used in the auxiliary burners shall be treated as if it had been burned in the combustion turbine. However, this is not intended to apply to situations where the downstream burners have a larger heat input than the combustion turbine such as the case when a combustion turbine provides combustion air to a large utility boiler.

iii) To determine the useful energy output over and above electrical or shaft power production, it is only necessary to measure the difference between the energy of the thermal fluids leaving and returning to the combustion turbine facility, and to demonstrate that the bulk of this energy is extracted in a useful application. This avoids having to individually measure the energy consumed by each downstream thermal energy application process in determining the heat output allowance.

5.0 EMISSION LIMITS

5.1 Emission Limits for NO_x

The emission limits for various types of combustion turbines are determined by calculation of the allowable mass of NO_x (grams) per unit output of shaft or electrical energy (gigaJoules), as well as an allowance for an additional quantity of NO_x emitted if useful energy is recovered from the exhaust gas as heat. Allowable emissions equal:

(POWER OUTPUT x A) + (HEAT OUTPUT x B)= grams of NO_2 equivalent

where,

POWER OUTPUT is the electricity and shaft power energy production of the combustion turbine, expressed in gigaJoules on an hourly basis (3.6 GJ per MW-hour).

HEAT OUTPUT is the total useful heat energy recovered from the combustion turbine as heat, expressed in gigaJoules (hourly basis).

"**A**" and "**B**" are the allowable emission rates, expressed in grams per gigaJoule, for the facility's power and heat recovery components respectively, as summarized below.

Table 1: **POWER OUTPUT ALLOWANCE "A" (g/GJ)**

	Natural Gas	Liquid Fuel
Non-Peaking Turbines		
Less than 3 MW	600	1250
3 - 20 MW	240	460
Over 20 MW	140	380
Peaking Turbines		
Over 3 MW	280	530

Notes:

i) The 3 and 20 MW break points refer to the power output of the combustion turbine (not including any steam turbine or heat recovery).

ii) For the initial one-year period (until November 30, 1995) of the Guideline, the emission allowances for 3-20 MW sized non-peaking units are 350 g/GJ and 600 g/GJ, for gaseous and liquid fuels respectively.

iii) The value of "**A**" has been set at 500 g/GJ for solid-derived fuels which recognizes that the competing alternative technology option is a conventional coal-burning steam electric power plant.

Table 2: HEAT RECOVERY ALLOWANCE "B" (g/GJ)

	Natural Gas	Liquid	Solid-Derived
For All Units	40	60	120

5.2 Emission Limit for Carbon Monoxide (CO)

For units covered by the NO_x provisions of this Guideline, emissions of CO corrected to Reference Conditions at 15 percent oxygen and on a dry volume basis shall not exceed:

- 60 parts per million per volume basis (ppmv) at the combustion turbine's power rating.

Note: Recent information from users/manufacturers of combustion turbines indicates that a level of 50 ppm is barely achievable when meeting lower NO_x levels. Therefore, a tolerance of 10 ppm (20%) has been added. The CO limit of 60 ppm may be adjusted in the future, depending upon actual performance data.

5.3 Emissions of Sulphur Dioxide (SO_2)

Sulphur dioxide emissions from combustion turbines can be limited by using low sulphur content fuels, or by using technologies which reduce the fuel sulphur content or which capture sulphur dioxide emissions in the exhaust. Sulphur dioxide emissions shall not exceed the following limits:

i) Liquid and Gaseous Fuels

For non-peaking units, 800 grams per gigaJoule of shaft, electrical and heat energy output, and for peaking units, 970 grams per gigaJoule of output.

ii) For Solid-Derived Fuels

770 grams per gigaJoule of shaft, electrical and heat energy output for those fuels whose uncontrolled SO_2 emissions based on fuel sulphur content would be between 770 and 7700 g/GJ of output, or a minimum of 90% sulphur capture for those fuels whose uncontrolled SO_2 emissions based on fuel sulphur content would be greater than 7700 g/GJ of output.

However, units with a power rating of less than 3 MW which are used exclusively to power natural gas field compressors upstream of natural gas processing facilities are exempt from the SO_2 limits.

6.0 IMPLEMENTATION OF THE GUIDELINE

The requirements of this Guideline will be implemented through conditions on Certificates of Approval issued for units where the Ministry received the application for Certificate of Approval on or after November 30, 1994.

To simplify the record keeping and compliance monitoring procedures of the proponent and Ministry abatement staff, respectively, the limits for NO_x, CO and SO_2 (if applicable) will be expressed on the Certificates of Approval as a concentration (ppmv). Procedures to convert emission limits to ppmv

(Reference Conditions and 15% Oxygen on a Dry Volume Basis) are described below:

Oxides of Nitrogen (NO_x)

$$Emission\ \ Limit\ \ (\ ppmv\ @\ 15\%\ O_2\ )\ =\ \frac{C*E}{D}$$

where,

C = Combined Power & Heat Output Allowance (g/GJ Output)

$$= \frac{\text{POWER OUTPUT x A}}{\text{POWER + HEAT OUTPUT}} + \frac{\text{HEAT OUTPUT x B}}{\text{POWER + HEAT OUTPUT}}$$

A,B are from Tables 1 and 2, Section 5
HEAT OUTPUT and POWER OUTPUT will be provided by the proponent.

E = Efficiency Factor at maximum rating and Reference Conditions

$$= \frac{\text{Thermal Efficiency (\%) of Combustion Turbine and Heat Recovery}}{100}$$

The Thermal Efficiency will be provided by the proponent.

D = Fuel Constant

(The following fuel constants can be used for natural gas or typical fuel oils):

= 1.70 g NO_2 per GJ of heat input per ppmv @ 15% O_2 for natural gas fuel

= 1.77 g NO_2 per GJ of heat input per ppmv @ 15% O_2 for liquid fuel

Carbon Monoxide (CO)

60 ppmv @ 15% O_2 as per Section 5.2 of this Guideline.

Note: A reference condition of 15% O_2 by volume-dry has been selected to reflect typical operating conditions for stationary combustion turbines.

Sulphur Oxide (SO_2)

The procedure is the same as the one described above for NO_x:

$$Emission\ \ Limit\ \ (\ ppmv\ @\ 15\%\ O_2\ )\ =\ \frac{C*E}{D}$$

where,

C = Output Allowance, as indicated in Section 5

E = Efficiency Factor; calculated the same as above.

D = Fuel Constant
= 2.37 g SO_2 per GJ of heat input per ppmv @ 15% O_2 for natural gas fuel
= 2.46 g SO_2 per GJ of heat input per ppmv @ 15% O_2 for liquid fuel

Alternatively, the SO_2 limit can be expressed as an equivalent weight percent of sulphur in the fuel.

7.0 VERIFICATION OF COMPLIANCE WITH EMISSION LIMITS

To confirm that the stationary combustion turbine facility has the ability to operate in compliance with the provisions of this Guideline and the Certificate of Approval, source testing or continuous emission monitoring will be required. The following sections provide the necessary verification procedures:

7.1 Continuous Emission Monitoring (CEM) Requirements

APPLICABILITY: Non-Peaking Combustion Turbines Larger Than 25 MW Power Output That Are Used to Generate Electricity

CEM devices should be provided to non-peaking units larger than 25 MW for the measurement of NO_x, CO and O_2 according to the United States Environmental Protection Agency performance specification #2 (for NO_x, with a relative accuracy requirement of 10%), #3 (for O_2), and #4 (for CO) under 40CFR60, Appendix B of the United States Federal Register. This Guideline may be modified in the future to allow for other performance specifications as more information becomes available. The Guideline may also be revised to allow for alternate methods that are equivalent to continuous emission monitoring devices, such as parametric monitoring, as they become available.

SO_2 emissions should be estimated (if applicable) based upon a mass balance and the expected range of sulphur content in liquid and solid fuels used by the combustion turbine.

7.2 Source Testing Requirements

APPLICABILITY: Non-Peaking Combustion Turbines Equal to or Smaller than 25 MW Power Output;

Non-Peaking Combustion Turbines Larger Than 25 MW Power Output That Are Not Used to Generate Electricity; and

All Peaking Turbines Greater Than 3 MW.

Source Testing for Non-Peaking Combustion Turbines which are equal to or less than 25 MW should be conducted for NO_x, CO, and SO_2 (if applicable) initially, after commissioning, and thereafter every 2 calender years. Three (3) source tests shall be conducted at maximum rating or at the maximum load achievable at the time of testing.

Source tests for Peaking Combustion Turbines should be conducted for NO_x, CO and SO_2 (if applicable) initially, after commissioning, only. Three source tests shall be conducted at maximum rating or at the maximum load achievable at the time of testing.

All source tests should be conducted according to the Ontario Source Testing Code and the United States Environmental Protection Agency Method 7E, 6C and 10B for NO_x, SO_2 and CO, respectively. A pre-test plan for the initial source testing campaign should be submitted to the Ministry. The Ministry should be notified at least 1 month in advance of the commencement of any source testing and on an auditing basis, the Ministry may witness the source testing.

7.3 Verification of Thermal Efficiency

APPLICABILITY: All Combustion Turbines that are not exempt from this Guideline.

The emission concentration limits for NO_x and SO_2, that will be included on the Certificate of Approval for the Combustion Turbine, are derived from the Power and Heat Output Allowances included in section 5.1 of this Guideline and the anticipated thermal efficiency

provided by the proponent. Therefore, to ensure the validity of the estimated thermal efficiency, testing of the Combustion Turbines thermal efficiency will be necessary.

A verification of the average operating thermal efficiency of a Combustion Turbine should be conducted whenever there is source testing or in the case of units equipped with CEM devices initially and thereafter every 2 calender years. The thermal efficiency verification should provide measurements (at maximum rating or at the maximum load achievable at the time of testing over an averaging period of not less than 3 hours) to determine the following parameters:

i) Power Output (MW): based upon measurements of shaft and electrical power output.

ii) Heat Output (MW): based upon total heat energy recovered from the combustion turbine exhaust gases (eg. based upon measurements of inlet and outlet enthalpy of water/steam in the case when water heaters or steam generators are used to extract heat from the exhaust gases).

iii) Fuel Flow (m^3/s) or (kg/s).

iv) Lower Heating Value (LHV) of the Fuel (MJ/m^3) or (MJ/kg).

v) Ambient air temperature, barometric pressure and relative humidity.

vi) Date, time and duration of test.

The thermal efficiency of the Combustion Turbine should be calculated as follows:

$$E = \frac{\text{Output}}{\text{Input}} \times 100\% = \frac{(\text{Power} + \text{Heat Output})}{\text{Fuel Flow} \times \text{LHV}} \times 100\% \quad ; \text{and}$$

converted to Reference Conditions

If the measured thermal efficiency is less than the anticipated thermal efficiency (with a tolerance of 0.05 multiplied by the anticipated thermal efficiency) used to derive the emission concentration limits on the Certificate of Approval then the proponent should notify the Ministry and the concentration limits on the Certificate should be revised accordingly.

7.4 Demonstration of Compliance

For units equipped with continuous emission monitoring devices compliance is demonstrated if the monitored contaminant emission results, on a 24 hour rolling average basis, are less than the appropriate emission concentration limits of the Certificate of Approval. For units that regularly conduct emission measurements, compliance is demonstrated if the average of the three source tests are less than the appropriate emission concentration limits of the Certificate of Approval.

8.0 RECORD KEEPING REQUIREMENTS

The proponent of a Combustion Turbine Facility will have the responsibility of ensuring compliance with the requirements of the Certificate of Approval and shall maintain records of compliance according to the following sections.

8.1 Record Keeping for Units Equipped with CEM Devices

i) Raw data from the CEM devices in the form of a strip chart or computer printout or computerized format.

ii) A monthly summary of 24 hour average readings from the CEM devices should be maintained and provided with the following information:

- Date, start time and end time for each 24 hour averaging period;
- Oxygen reading (% by volume-dry) and stack gas temperature (^{o}C);
- 24 hour average concentration of NO_x and CO (ppmv @ 15% O_2);
- Results of daily zero and span calibrations of the CEM device: measurements from the zero calibration, span gas concentration and CEM device readings of the span gas concentration;
- standard deviation of the measurements for each 24 hour average period.

8.2 Record Keeping for Source Testing

A report should be completed within 6 months of commencement of source testing. The results of each testing campaign should provide the following information:

- Date, time and duration of each test;
- Ambient air temperature, barometric pressure and relative humidity during test;
- The oxygen (% by volume) concentration and stack gas volumetric flow rate (m^3/s at Reference Conditions);
- Emission concentrations of NO_x, CO and SO_2 (ppmv @ 15% O_2);
- Stack gas temperature (^oC);
- Average of emission concentration readings (ppmv @ 15% O_2) for the 3 tests conducted.

8.3 Record Keeping for Thermal Efficiency Verification

A summary of the results of the thermal efficiency verification should be completed within 6 months of commencement of the efficiency testing and should provide the following information:

- Date, time and duration of test;
- Ambient air temperature, barometric temperature and relative humidity during test;
- Electrical Power Output (MW);
- Shaft Power Output (MW);
- Heat Output (MW);
- Steam Flow (kg/s);
- Steam Pressure (kPa);
- Steam Temperature (^oC);
- Feedwater Temperature (^oC);
- Fuel Flow including auxiliary burners (m^3/s or kg/s);
- Fuel LHV (MJ/m^3 or MJ/kg).

All of the above record keeping (CEM device raw data, 24 hour average CEM device data; test and summary reports) should be maintained for a minimum of 2 years and should be made

available to the Ministry upon request.